March 8, 2016

MEMORANDUM

To: Jill Morrison
Powder River Basin Resources Council
Sheridan, WY

From: Mike Wireman
Granite Ridge Groundwater
Boulder, CO

Re: Review comments – Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study; AME, Inc.; December 14, 2015

I have completed a review of the above referenced report, appendices and selected references. Overall the report provides a reasonable assessment of the hydrocarbon contamination of shallow groundwater within the Wind River Formation in the vicinity of the Pavillion Gas Field located east of the Town of Pavillion in Fremont County, WY. It is important to recognize that the Pavillion Gas Field is a large industrial operation which utilizes a variety of industrial chemicals which can infiltrate into the sub-surface and contaminate shallow groundwater. Production of gas has clearly resulted in enhanced migration of thermogenic gas which has contaminated shallow groundwater in the upper part of the Wind River Formation and contaminated a number of domestic/stock wells. Given the extent of the contamination I suggest that the Pavillion Gas Field be considered a major groundwater contamination site that should be regulated and remediated.

The report includes very specific recommendations (Chapter 6)for continuing investigation that are aimed at providing data that will more fully explain the occurrence and bio-geochemistry of the contaminants related to bio-degradation of hydrocarbon compounds. These recommendations should absolutely be adopted and completed.

Important findings

1. Significant commercial gas deposits occur in the Wind River Fm (and the underlying Ft. Union Fm.) at depths greater than 1500 feet. Non-commercial gas deposits occur at shallower depths – 500 fbgs. The report concludes that thermogenic gas is migrating upward into shallow zones in the Wind River Fm (less than 500 fbgs) that are being used by private domestic / stock wells. Upward migrating gas has been a primary cause of contaminated domestic / stock wells.

2. Migration is occurring along two types of pathways:

a. (1) Natural geologic pathways - the Wind River Fm has significant permeability in places and there is no regional low permeability lithologic unit to constrain the upward migration the gas. The most productive part of the Wind River Formation (for water well yields) is from 800-1800 ft. However most stock / domestic wells are less than 500 feet deep.
b. (2) Borehole related pathways – At least 17 of the 52 gas wells, located within 1420 feet of one of the 14 water supply wells sampled for this study, have an open annulus between the bottom of the surface casing and the top of the production casing cement. An additional 9 gas wells have an open annulus between the production casing and the surface casing. These vertical zones are often connect intermediate zones (with gas deposits) and shallow zones used for water supply. Gas can also migrate through channels in the production or surface casing cement. Gas can migrate laterally away from the open annulus into shallow water bearing zones within the Wind River Fm. At least 11 of the 52 gas wells had sustained Bradenhead pressure, indicating leakage. An additional 9 gas wells have an open annulus between the production casing and the surface casing.

3. Increase oil production activity, including the change in well spacing from one well per 640 acres to one well per 40 acres in 2000 has resulted in a huge increase in potential subsurface pathways for upward gas migration. This, more dense spacing, also increases the chance of encountering shallow non-commercial gas deposits.

4. A number of petroleum constituents, organic compounds, semi-volatile organic compounds and dissolved methane have been detected in groundwater from the 14 wells sampled for this study. While generally at low concentrations, these compounds are found in numerous products used in oil and gas development. Sources of these constituents include surface related production activities, well drilling and construction fluids and sub-surface gas deposits.

5. Bio-degradation of dissolved organic compounds, including natural thermogenic gas, by bacteria is an important bio-geochemical process in groundwater. Iron bacteria and sulfate-reducing bacteria growth is enhanced if there is a significant source of dissolved gas. At least one sample from 13 of the 14 wells included in the study had measurable, high counts of iron bacteria, sulfate-reducing bacteria, heterotrophic bacteria, and / or slime forming bacteria.) High counts of bacteria in well water produces constituents that foul water making it less palatable and may plug the well screen, reducing well yield.

6. There are approximately 55 unlined pits in Pavillion Gas Field and 25 are within 1420 ft of one of the 14 sampled wells. Only a few of these pits have been adequately characterized and remediated. These pits remain a potentially significant source of ground water contaminants.

Major comments

1. The WOGCC, WDEQ and industry have known about shallow gas deposits in the Wind River Formation in this part of the Wind River Basin for decades (since 1960s). Why have no institutional controls been put in place by WDEQ / WSEO to prevent / limit drilling and completion of stock /domestic wells in locations and at depths that might encounter shallow gas deposits? Why did WOGCC not require production casing to be cemented to surface?

2. Too few (14) water supply wells were sampled in the study. There are 97 water supply wells within the cistern area. The criteria used to select wells were too limiting and data from this limited set of wells cannot be used to: (a) assess how widespread the hydrocarbon contamination is within the shallow part of the Wind River Formation, (b) evaluate fate and transport of hydrocarbon compounds (petroleum products) and (c) design an adequate groundwater monitoring network to monitor groundwater within and around the Pavillion Gas Field.

3. I disagree with the conclusions (Sections 5.1.4 and 5.1.5) that: (a) "existing data is insufficient to demonstrate that the presence of methane or changes in water quality in domestic water supply wells is associated with gas development" and (b) "seepage of gas or other fluids from production zones along abandoned gas wells is unlikely". In my opinion the data, while limited spatially and temporally, clearly indicates hydrocarbon contamination of shallow groundwater, which if considered along with the increased gas well spacing density and the obviously common wellbore integrity pathways, is convincing evidence that the development of gas from the Pavillion field has increased the migration of thermogenic gas upward into shallow water bearing zones of the Wind River Fm. and resulted in contamination of numerous water supply wells.

4. Section 2.5.4 – this discussion is very confusing. How does WDEQ / WOGCC determine boundaries of water bearing zones within the Wind River Fm. that meet the definition of a USDW or WY Class 6 groundwater? Are these designations done only well by well basis? Or are boundaries established? If so are these designations available to the public? In this section it is also stated that WY Class 1,2,3 groundwater (TDS < 5000) is equivalent to the SDWA definition of a USDW. This is not true. the SDWA definition includes ground waters with TDS values < 10,000 mg/l.

5. The depth to water data (groundwater elevation) is not very useful. Depth to water data was collected for only five wells and only pumping water levels were obtained. These data cannot be used to evaluate the configuration of the water table, direction of groundwater flow, water level trends.

6. Section 5.3.3 - The distinction between "naturally occurring methane" and "gas seepage along wells bores" is misleading. The methane is all natural, in that it occurs in sub-surface deposits. The distinction is related to the migration pathways – which include "natural" geologic pathways and wellbore pathways.

7. The Wyoming Class I domestic standard for gross alpha is incompatible with the EPA MCL because the Wyoming standard is for "gross alpha particle radioactivity" – which excludes uranium and radon. The EPA gross alpha MCL standard applies to all gross alpha activity.
8. The report should include a more detailed discussion on fate and transport of gas and dissolved methane through the subsurface.

9. The selection criteria requiring that the water supply well was installed deeper than the surface casing of gas wells located within 1000 ft assumes gas will not migrate upwards past bottom of surface casing. What is the basis for this assumption? Why was 60F not sampled for water quality?

Suggested edits and recommendations

1. The groundwater contamination at the Pavillion Gas Field points out the clear need for pre-development groundwater monitoring to establish baseline water quality conditions. It also demonstrates the need for ongoing monitoring during operation and post-closure. WDEQ and WOGCC should strongly consider requiring groundwater monitoring where oil and gas development will occur.

2. Dissolved uranium concentrations exceed 15ug/l in 24 of the samples collected for this study. Activity values for gross alpha and radon are also high in numerous samples. This indicates significant uranium content in sediments that comprise the Wind River Fm. This should be discussed in more detail in the report with an assessment of the risk to domestic /stock water supplies.

1. Section 4.2.6.1 – It is stated here that analysis of DRO with SGCU results in data that are "more representative of petroleum products" because polar compounds are removed. It should be noted that polar organic compounds derived from bio-degradation of petroleum products are also indicative of petroleum hydrocarbons.

2. Soil gas surveys should be conducted on a regular schedule in areas around gas wells with high Bradenhead pressures to look for upward migrating gas. In addition a groundwater monitoring well should be installed downgradient of one of these gas wells.

3. Figure 5 is a poor geologic map. This map should have a better depiction of surficial deposits.

4. The table included in Section 2.5.3 should include the number of samples for each analyte.

5. On Table 9, in Column 5 – there should be information as to whether the septic tank is up-gradient or down gradient of the water supply well

6. The report should provide any existing data for hydrocarbon constituents (petroleum products) in Five Mile Creek water –DRO, GRO, methane, etc. If none exist, Five Mile Creek should be sampled for these constituents.

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